

What is Claimed:

- 1 1. A multiple component refrigerant comprising at least two
2 components, with each component selected from one of the groups consisting of: (a)
3 inert atmospheric gases; (b) normally gaseous and liquid fluorocarbons; (c) normally
4 gaseous and liquid hydrofluorocarbons; and (d) normally gaseous and liquid
5 hydrocarbons.
- 1 2. The refrigerant of claim 1 wherein the fluorocarbons contain
2 from 1 to about 5 carbon atoms, the hydrofluorocarbons contain from 1 to about 4
3 carbon atoms, and the hydrocarbons contain from 1 to about 5 carbon atoms.
- 1 3. The refrigerant of claim 1 wherein the inert atmospheric gases
2 are present in an amount of up to about 60 mol %, the fluorocarbons are present in
3 an amount of up to about 55 mol %, the hydrofluorocarbons are present in an
4 amount of up to about 55 mol %, and the hydrocarbons are present in an amount of
5 up to about 50 mol %.
- 1 4. The refrigerant of claim 1 wherein the hydrocarbons are present
2 in an amount and in proportion to the other components such that refrigerant is non-
3 flammable.
- 1 5. The refrigerant of claim 1 wherein the refrigerant comprises at
2 least two components with each component selected from a different one of the
3 groups consisting of: inert atmospheric gases; normally gaseous and liquid
4 fluorocarbons; and normally gaseous and liquid hydrofluorocarbons.

1 6. A multiple component refrigerant composition for use in a
2 closed cycle refrigeration system for producing cooling temperatures below 230°K
3 and above 70°K consisting of:

4 15 to 60% by volume of an inert gas selected from the group
5 consisting of helium, argon, neon, nitrogen or mixtures thereof;

6 25 to 50% by volume of a fluorocarbon; and

7 0 to 50% by volume of a hydrofluorocarbon.

1 7. A composition according to claim 6 wherein said fluorocarbon is
2 selected from the group consisting of CF₄ and C₂F₆, C₃F₈ and mixtures thereof.

1 8. A composition according to claim 6 wherein said
2 hydrofluorocarbon is selected from the group consisting of CHF₃, C₂HF₅, C₂H₂F₄,
3 C₃H₂F₆, C₃H₃F₅, C₃HF₇, C₂H₄F₂, C₂H₃F₃, CH₂F₂ and mixtures thereof.

1 9. A composition according to claim 6 including from 10% by
2 volume to 85% by volume hydrocarbon instead of said fluorocarbon or said
3 hydrofluorocarbon.

1 10. A composition according to claim 9 wherein, the hydrocarbon is
2 selected from the group consisting of methane, ethane, propane, isobutene,
3 ethylene, normal butane, pentane, isopentane and mixtures thereof.

1 11. A method for improving a closed cycle refrigeration system
2 used to produce temperatures in the range of from about 70 to about 230°K the
3 refrigeration system having an oil lubricated compressor to produce high pressure
4 high temperature refrigerant, an oil separator to remove oil from the refrigerant an
5 after cooler to reduce the temperature of the high temperature high pressure
6 refrigerant, a filter/dryer to remove water from the refrigerant, a heat exchanger
7 wherein the high temperature high pressure refrigerant is cooled by heat exchange
8 with a low pressure low temperature refrigerant, a throttle device to expand the high
9 pressure refrigerant and produce a low pressure cold refrigerant at a point of use,
10 and means for returning the low pressure refrigerant to the oil lubricated
11 compressor, a gaseous refrigerant in said system, said refrigerant having no
12 components normally condensed in said after-cooler; comprising: placing said after
13 cooler immediately downstream of a high pressure outlet of said compressor and
14 before said oil separator, and using an oil separator having less than 7 psig pressure
15 drop between an inlet and an outlet and an oil carryover rate less than 0.001
16 grams/hour.

1 12. The method of claim 11 wherein the oil separator operates to
2 produce a refrigerant containing less than about 1% by weight lubricating oil.

1 13. A closed cycle refrigeration system to produce temperatures in
2 the range of from about 70 to about 230°K comprising in combination: a refrigerant
3 consisting of at least two components, with each component selected from any one
4 of the groups consisting of atmospheric gases, normally gaseous and liquid
5 fluorocarbons, normally gaseous and liquid hydrofluorocarbons, and normally
6 gaseous and liquid hydrocarbons; an oil lubricated compressor to pressurize said

7 refrigerant, an after cooler to receive and cool said pressure refrigerant, an oil
8 separator to receive said refrigerant and remove oil from said refrigerant so as to
9 produce a refrigerant containing less than 1% by weight lubricating oil in the
10 refrigerant, a filter/dryer to receive said refrigerant from said oil separator and
11 remove water from said refrigerant; a heat exchanger to receive said refrigerant from
12 said filter/dryer and cool said refrigerant by heat exchange with a low pressure
13 refrigerant return stream; a fixed orifice throttle device to receive said refrigerant
14 stream from said heat exchanger and expand said high pressure refrigerant to
15 produce a low pressure low temperature refrigerant stream, said throttle device so
16 constructed and arranged to provide during cooldown of said refrigerant from normal
17 ambient temperature more than about 60% of the maximum refrigeration capacity of
18 said system available during desired steady state operation of said system, resulting
19 in a low pressure low temperature refrigerant stream, means for utilizing said low
20 pressure low temperature refrigerant stream to provide cooling and means for
21 returning a warmed low pressure refrigerant stream to the oil lubricated compressor.

1 14. The closed cycle refrigeration system of claim 13 wherein the
2 refrigerant contains a hydrocarbon present in an amount to maintain the refrigerant
3 as non-flammable.

1 15. The closed cycle refrigeration system of claim 13 wherein said
2 refrigerant is a mixture of an inert atmospheric gas, fluorocarbons containing from 1
3 to about 5 carbon atoms, and a hydrofluorocarbons containing from 1 to about 4
4 carbon.

1 16. A closed cycle refrigeration system according to claim 13
2 wherein the refrigerant is a mixture of two components selected from one of the
3 group consisting of and normally liquid and gaseous hydrofluorocarbons.

1 17. A closed cycle refrigeration system according to claim 13
2 wherein the components of the refrigerant are selected such that the difference in
3 normal boiling points between any component and the next higher boiling point
4 component is no more than about 100°K.

1 18. A closed cycle refrigeration system according to claim 17
2 wherein the components of the refrigerant are selected such that the difference in
3 normal boiling points between any two components is at least about 1°K.

1 19. A closed cycle refrigeration system according to claim 17
2 wherein the components of the refrigerant are selected such that the normal boiling
3 points of the highest and lowest boiling components will differ from each other by
4 about at least 30°K.

1 20. A closed cycle refrigeration system for providing cooling
2 temperatures from about 70°K to 230°K comprising in combination: an oil lubricated
3 compressor for creating a high pressure refrigerant stream; an after cooler connected
4 to an outlet of said compressor to further cool said high pressure refrigerant stream;
5 an oil separator connected to an outlet of said after cooler, said oil separator adapted
6 remove residual oil from said high pressure refrigerant stream so that said high
7 pressure refrigerant stream exiting said oil separator contains less than 1% by
8 weight retained oil; means connected to said oil separator to extract water from said

9 high pressure refrigerant stream; a heat exchanger connected to said means to
10 extract water for further cooling said high pressure refrigerant stream against a
11 returning low pressure refrigerant stream; expansion means connected to said heat
12 exchanger to reduce the pressure of said refrigerant stream to produce a low
13 pressure low temperature refrigerant stream; means to utilize the low pressure low
14 temperature refrigerant stream to provide cooling; and means to return said low
15 pressure refrigerant to a low pressure inlet side of said compressor.

1 21. A closed cycle refrigeration system according to claim 20
2 wherein said expansion means is one of a capillary tube of fixed inside diameter and
3 fixed length, a fixed orifice plate, or a fixed position needle valve.

1 22. A closed cycle refrigeration system according to claim 20
2 wherein said oil separator is so constructed and arranged to have less than 7 psig
3 pressure drop between an inlet and an outlet and an oil carry over rate less than
4 0.001 grams per hour.

1 23. A closed cycle refrigeration system according to claim 20
2 wherein said oil separator has a maximum operating pressure of 400 psig.

1 24. A closed cycle refrigeration system according to claim 20
2 including an additional replaceable modular oil separator and modular means to
3 extract moisture from said refrigerant stream placed upstream of said heat
4 exchanger and downstream of said fixed oil separator.

1 25. A closed cycle refrigeration system according to claim 20
2 wherein said expansion means is a fixed orifice device so constructed and arranged

- 3 to enable said system to provide about 60% of the maximum steady state
- 4 refrigeration capacity of the system during cool-down from ambient temperatures to
- 5 a working temperature.